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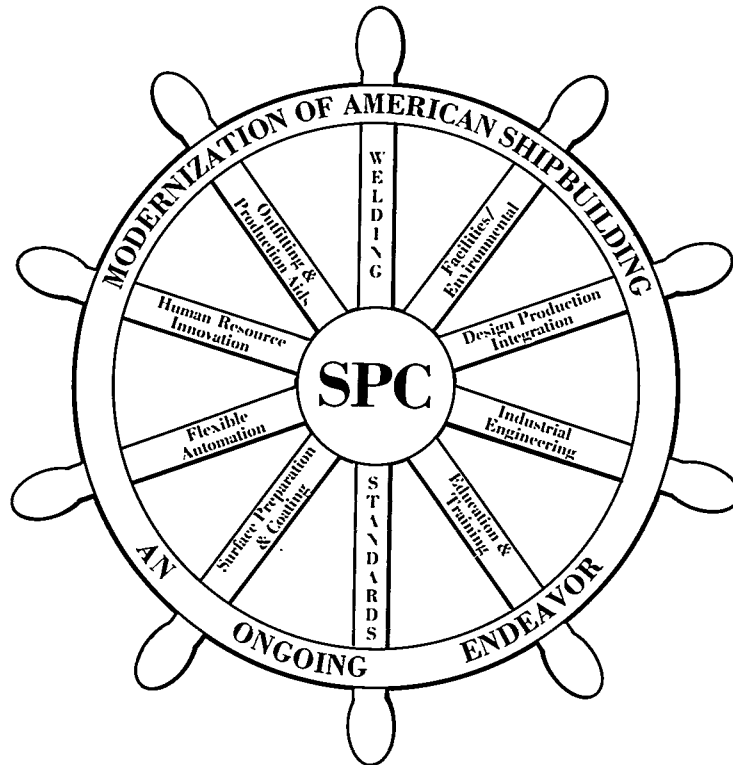
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Paper No. 2: IHI's Experience of Technical Transfer & Some Considerations on Further Productivity Improvement in U.S. Shipyards

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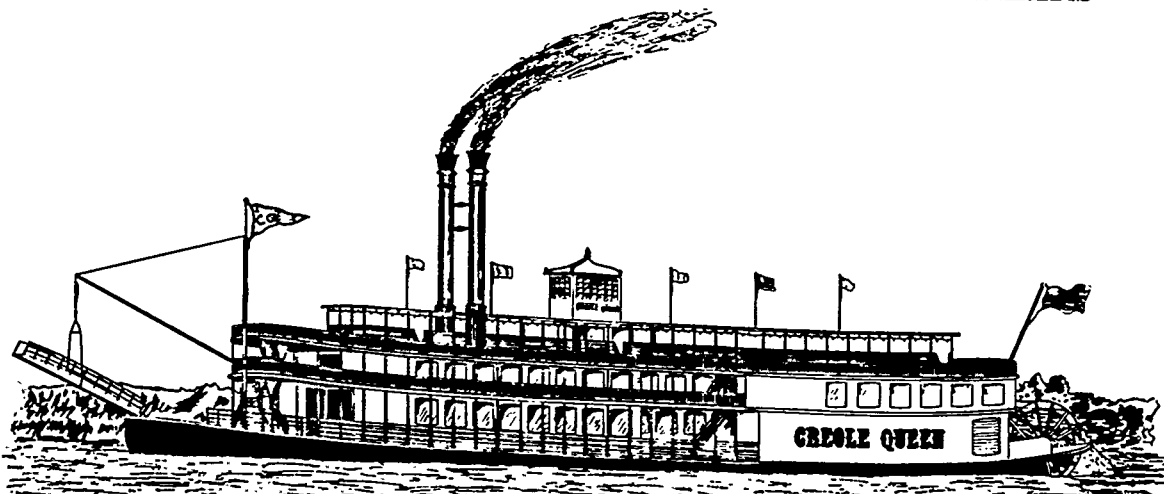
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IHI's Experience of Technical Transfer and Some Considerations on Further Productivity Improvement in U.S. Shipyards

No. 2

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ABSTRACT

Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI), a leading shipbuilder in Japan, has uniquely exported shipbuilding technology throughout the world for three decades. The North American efforts, starting in the mid seventies, were stimulated by the U. S. Government/Industry National Shipbuilding Research Program (NSRP). The technology transfer, for which the U.S. Maritime Administration (MarAd) deserves much credit, has significantly modernized and improved U.S. shipbuilding systems with carryover into naval shipyard operations for overhaul of all types of warships. But, productivity levels achieved thus far in the U.S., while impressive, are not nearly as great as those in Japan.

This paper is based on analyses of the underlying differences of shipbuilding systems, technology, and practices between those in Japan and in the U.S. Hopefully, descriptions of the state-of-the-art IHI technology will serve as guidance for further productivity improvements in the U.S.

1. INTRODUCTION

The history of Japanese modern shipbuilding technology began when National Bulk Carriers, Inc. (NBC), an American corporation, leased the former naval dockyard in Kure after World War II. NBC brought to Japan the block construction method and the welding technology which made block construction possible, i.e., the most modern American rationalization of shipbuilding that then existed. Dr. H. Shinto, who had worked as the Chief Engineer under Mr. E. L. Hann the NBC

team leader, systematized all the new elements so as to contribute to the development of the Japanese shipbuilding industry as it now exists (1). This is the modern Japanese shipbuilding technology which, starting in 1978, is being returned to the U.S. in a highly developed form.

But command of the transferred technology can be further improved in terms of productivity. From an IHI manager's viewpoint, the improvement effort should be focused not only on the technical elements, but also on human management. When the American shipbuilding technology was transferred to Japan, Japanese managers learned not only the technical aspects, but also something of the American pioneer spirit which contributed to later innovations in Japan.

Now, even after facility modernization consistent with a modern shipbuilding method, IHI systematically and routinely improves productivity as discussed herein.

2. PRODUCTIVITY IN JAPANESE SHIPBUILDING

2.1 CHANGES IN PRODUCTIVITY

In the latter half of the 1950s, Japanese shipbuilding tonnage became the largest in the world. Responding to the demands for larger tankers and bulk carriers, the industry promoted further modernization and expanded its facilities during the 1960s. By the beginning of the 1970s most major Japanese shipbuilding companies had yards which could construct ships of 500,000 - 800,000 DW tons.

By this time, the block construction method and zone outfitting method were highly developed by exploiting the principles of Group Technology. In other words, the decade starting in 1963 marked what may be called the golden period for ship-

building technology development. Then, the rate of productivity increase and levels of productivity achieved were unprecedented.

Figure 1 summarizes the history of modern shipbuilding in Japan starting with the NBC Kure operation.

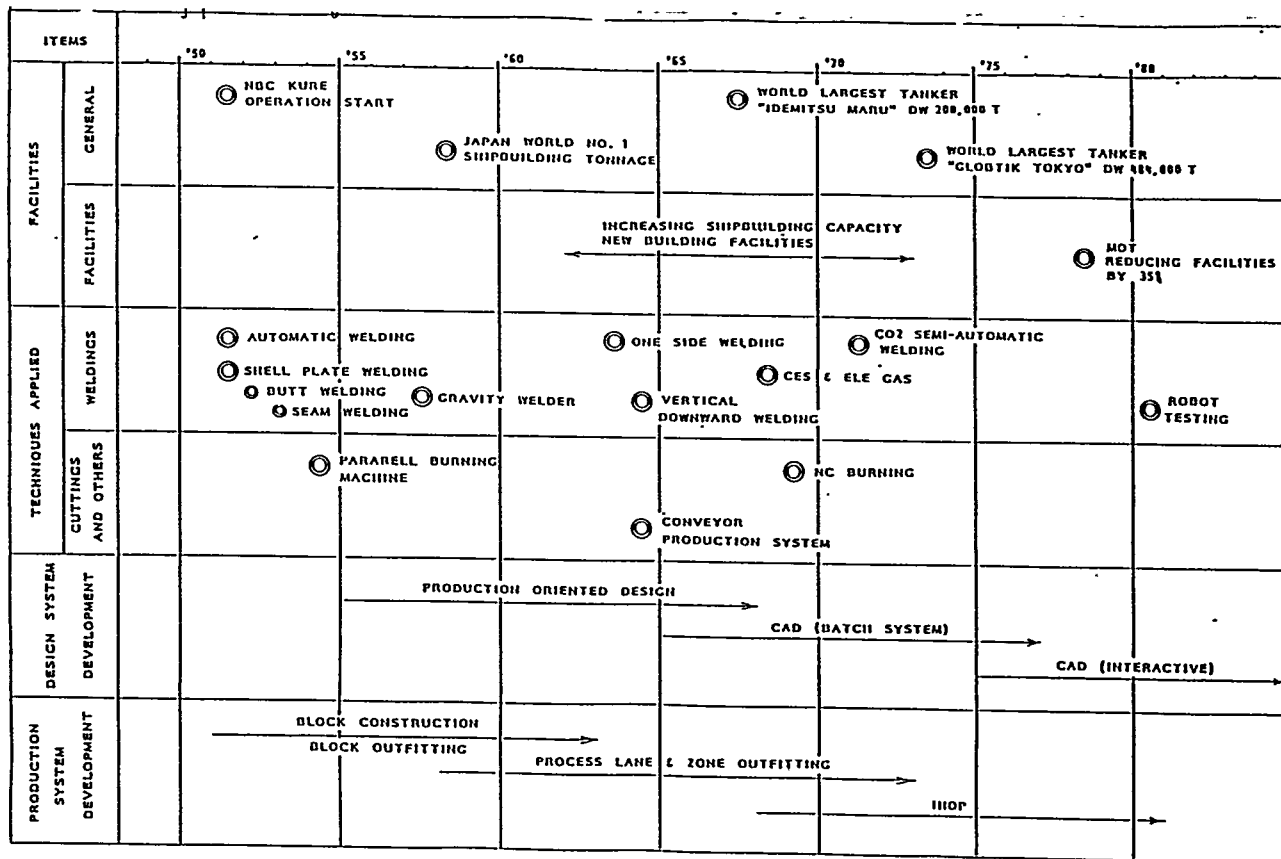


Figure 1. History of Japanese shipbuilding technology (1951-1985)

Following the 1973 oil shock the Japanese shipbuilding industry was confronted with a continuing crisis due to Japanese decline in demand. In 1978 the Japanese Ministry of Transport advised the industry to reduce shipbuilding facilities by 35 percent. Thus, some of the newly constructed large yards were converted into plants building products other than ships without full utilization of their modern facilities.

Development of the Korean and Taiwanese shipbuilding industries also contributed to the further decline of the Japanese shipbuilding industry. The competition for orders became increasingly more severe. In order to survive in this environment, cost reduction measures have become very important. IHI, no exception, is trying to survive by exerting all possible efforts for, and has made some progress in reducing costs significantly.

Figure 2 indicates the world shipbuilding tonnage completed from 1970 through 1985. As it is based on completions, the figure reflects demand trend with a time lag of about 2 years. After a peak in 1975 construction rapidly declined, reaching a nadir in 1980. As the figure shows, immediately afterwards, building tonnage for the Korean industry increased noticeably.

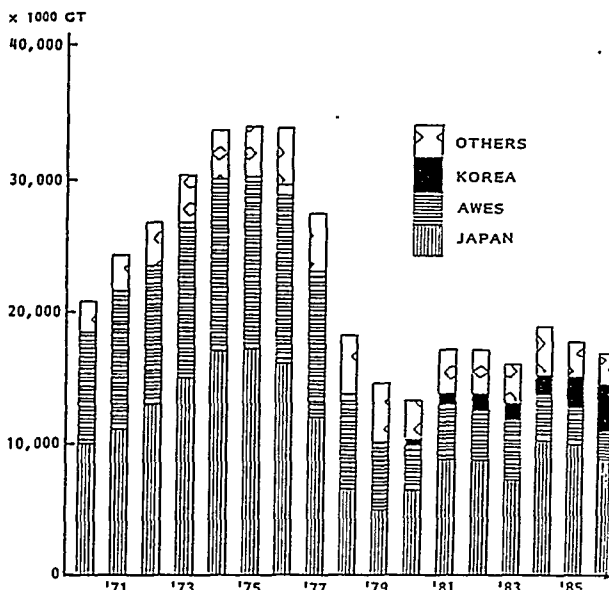


FIG. 2 NEW MERCHANT VESSELS BUILT IN THE WORLD
SOURCE; LLOYD REGISTER OF SHIPPING (2)

Figure 2. New merchant vessels built in the world
Source: Lloyd register of shipping (2)

Figure 3 is a plot of IHI's man-hour reduction rate for building 30,000 - 60,000 DWT bulk carriers for the 10 years between 1968 and 1978. As shown, a reduction of 35 percent was achieved.

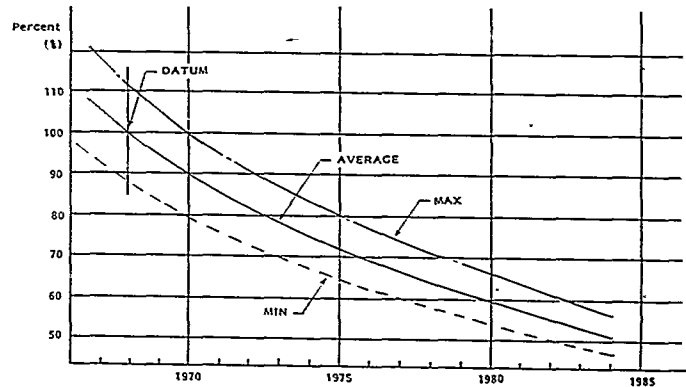


Figure 3. Man-hour reduction curve (30-60 type bulk carrier)(3)

Figure 4 shows how IHI improved efficiency for building commercial ships in recent years. The efficiency index was calculated by dividing the total man-hours consumed per year by the aggregate Compensated Gross Tonnage (CGT) of ships built in the same year, assuming the value in 1979 as 100. For the seven year period, 1979-1986, efficiency improved by 35 percent, i.e., 5 percent per year.

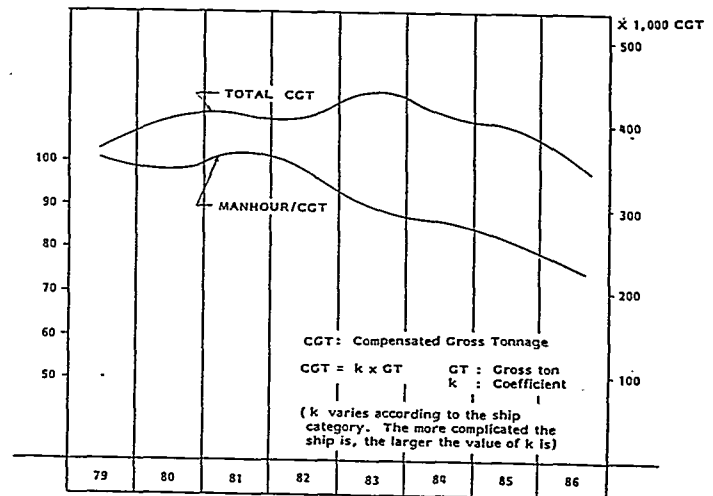


Figure 4. Man-hour/CGT curve

2.2 COST COMPARISON BETWEEN JAPANESE AND AMERICAN SHIPYARDS

In 1978, in response to a unique MarAd initiative as a part of the National Shipbuilding Research Program (NSRP), IHI disclosed its cost breakdown for building a 36,000 DWT bulker. The breakdown was used as a baseline for comparing cost estimates for the same ship if built in a U.S. shipyard. Estimates submitted for the same ship design disclosed that U.S. required man-hours were 3.5 times greater.⁽⁴⁾

With the "hard" data so obtained other comparisons for the 36,000 DWT bulker disclosed:

	<u>Built in Japan</u>	<u>Built in U.S.A.</u>
Cost	\$20,000,000	\$40,000,000
Delivery	12 months	26 months

Source: American Shipper, June 1979

Figure 5, prepared by a U.S. based tanker owner, is a comparison of estimated costs for 90,000 DWT tankers built in the United States, Northern Europe and Japan as of 1981.

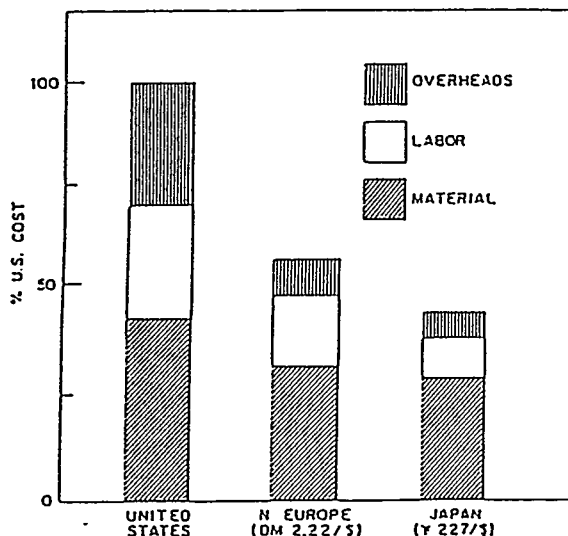


Figure 5. 90 kDWT crude carrier relative construction costs in U.S., N. European and Japanese shipyards for 1981 contract. (5)

As shown, major differences lie in the labor and overhead components of the estimates.

For the same 90,000 DWT tanker constructed in 1981 for delivery in

1983, the following comparison also apply:

	<u>USA</u>	<u>N. Europe</u>	<u>Japan</u>
Labor hours	100%	57%	46%
Labor cost	100%	51%	35%

But IHI managers who served as consultants concluded by 1984 that at least one U.S. shipyard had improved productivity by at least 30 percent because of the introduction of the new shipbuilding technology. This view was also reported by another interested observer (1). Other U.S. shipyards also benefited and as of 1987, from a productivity viewpoint, the ratio for Japanese yards relative to U.S. yards is 1 : 2 to 2.5.

3. TECHNICAL TRANSFER FROM IHI TO SHIPYARDS IN THE UNITED STATES

3.1 IHI'S TECHNICAL TRANSFER ACHIEVEMENTS IN THE UNITED STATES

The National Shipbuilding Research Program (NSRP) started in 1970 in order to improve the productivity of the U.S. shipbuilding industry. IHI began to participate in the NSRP in 1976 in response to two independent and simultaneous initiatives. One precipitated by MarAd's office of Advanced Ship Development led to IHI engineer-managers advising Livingston Shipbuilding Company in the application of modern methods for the construction of IHI designed 36,000 DWT bulkers. The other, initiated by Panel SP-2 of the Society of Naval Architects and Marine Engineer's Ship Production Committee, resulted in the NSRP publication "Outfit Planning" in 1979. The latter, which is highly descriptive and illustrative, gave a large number of U.S. shipbuilders their first understanding of the logic and principles employed for IHI shipyard operations. That publication and subsequent publications initiated by Panel SP-2, particularly "Product Work Breakdown Structure" first issued in 1980, were copied, translated, even into Japanese, and benefitted shipbuilders concerned with modern methods everywhere.

Thus, MarAd's early initiative alerted a number of key people that differences in management methods, not work ethic, was primarily responsible for the superior performances of Japanese shipyards. One of the people, Mr. A. L. Bossier, Jr, President of Avondale Shipyard, knowledgeable of the seriousness of the coming worldwide shipbuilding recession, was quick to engage IHI consultants in 1979 and rapidly manage a major transition to modern shipbuilding methods. The improvements were quickly manifest.

Shipyard	Project	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
LEVINGSTON SHIPBUILDING CO.	Enhancement of productivity Improvement of yard plan Supply of drawings for 32,000 DWT bulk carrier										
AVONDALE INDUSTRIES INC.	Enhancement of productivity Supply of drawings for container ship/product carrier Design & planning assistance										
NATIONAL STEEL & SHIPBUILDING CO.	Technical survey for productivity of new shipbuilding Consulting & engineering service in design and production for 209,000 DWT Tankers										
BATH IRON WORKS CORP.	Advanced technology program for Design, material & planning systems										
LOCKHEED SHIPBUILDING CO.	Enhancement of productivity Improvement of yard plan										
TAMPA SHIPYARD INC.	Supply of drawings for 30,000 DWT tankers										
PENNSYLVANIA SHIPBUILDING CO.	Facility improvement Engineering assistance Production assistance										
PHILADELPHIA NAVAL SHIPYARD	Application of zone logic for Ship repair										

Figure 6. Technical collaboration schedule

Other U.S. shipyards, in order to maintain competitive positions, also retained IHI engineer-managers as consultants as shown in Figure 6. Avondale having made the greatest effort in technology transfer relatively early, has since demonstrated an impressive competitive record. In today's business atmosphere, Avondale's competitive record thus far is evidence that it is not enough to pursue modern technology. For success, a yard must be "leading the pack" in its application.

As Figure 6 shows, although the content of technology transfer can be divided into many different categories, the main subjects pertained to assisting in design development for particular ships and for general productivity improvement.

The design efforts included preparation of drawings and technical documents with particular emphasis on work instruction drawings consisted with a product work breakdown structure.

Technology transfer for productivity improvement covered various fields such as design, production, production planning, material management, etc. The following section summarizes their main items and contents. Purposes are described here without details since they are introduced in various NSRP publications.

(1) "PRODUCT-ORIENTED DESIGN SYSTEM"

This system features a sequence of design processes, i.e. basic design, functional design transition design, and detail design (work instruction design).

The main purpose is to create and present all necessary information for preparing materials, purchasing equipment, and constructing the ship in the manner of the process lane and zone outfitting methods.

All information is issued in a format that allows it to be easily accessed and understood in the variety of uses for which it is intended.

(2) "STANDARDIZING"

The purpose of standardizing is to reduce the number of categories and quantities of materials. Productivity indicators are then not disrupted by widely varying materials. As a result, material management and processing are simplified and work efficiency improves.

(3) "MATERIAL MANAGEMENT SYSTEM"

The purpose of this system is to

supply necessary materials when they are needed to the locations where they are needed (just in time: JIT). For this purpose, materials are categorized into allocated material, stock material, and allocated stock material and managed by defining and managing their delivery dates. Furthermore, the functions of the warehouse and marshalling yards as well as palletizing are clearly defined.

(4) "PROCESS LANE SYSTEM"

This system categorizes all the processes into groups consisting of those with similar work content and allocates them to specified areas in the yard. The purpose of the system is to guarantee stable product quality and to improve productivity by fixing the workers in the specified areas. The results are specialized facilities, respective production management units, and workers groups with special skills, all of which contribute to improvement.

(5) "ZONE OUTFITTING"

Block construction and on-block outfitting had been used before IHI began its technical cooperation with U.S. shipyards.

Zone outfitting consists of on-block outfitting, fitting packages, and on-board outfitting. It requires elaborate planning at the design stage with the participation of production engineers, ample discussion, and preparing and gathering necessary materials and equipment for the respective zones and stages by defined times (which are earlier than conventional timing). Therefore, the product-oriented design and material management systems mentioned before are absolutely necessary.

The purpose of this method is to execute outfitting in an environment with more ease and safety (workers work downhand without scaffolding). Also, the purpose is to minimize the movement of both workers and materials from one zone to another by completing work per zone without workers shifting back and forth from one zone to another. This method is similar to that adopted during high-rise building construction where the interior work is completed by each story.

(6) "ACCURACY CONTROL"

The purpose of accuracy control is to minimize rework, especially minimizing adjustments of hull blocks during erection.

For this purpose, the precision of interim products is improved, without

using a great amount of labor, by revising production methods.

(7) "LINE HEATING"

Line heating is employed not only for bending and straightening steel plates and shapes by heating, but also for evaluating whether those materials are precisely processed with ease and precision. This contributes to minimizing unnecessary rework at following stages.

3.2 EVALUATION OF TECHNICAL TRANSFER

With the introduction of new technology, labor hours reduced considerably, although the reduction did not reach the level IHI had expected. The American shipyards must further and thoroughly execute the new systems and improve their own production systems in the future. However, there is a limit to the effects of introducing individual systems. The real task in the future, therefore, is to integrate those systems for which statistical control techniques are needed.

In integrating those systems, the role of the design process is still important. But sometimes, the design section of each yard does not recognize the importance of their own role. The improvement must be considered also from the information integration viewpoint.

Regarding productivity improvement, which is most important, the systems capable of quantitatively grasping and tracking work have been insufficient. Only a limited number of people are aware of the problem. The principle of executing the system by all workers has not yet been implemented. In such unintegrated situations, it is rather difficult to identify and solve problems.

People who perform production engineering seem rather passive and their production strategy, if any, is not considered for design development. Also, they are not given detailed information of how work processes are performing. Therefore, they can not sufficiently contribute to day-to-day productivity improvements nor provide good feedback to design. Design engineering and production engineering must be integrated.

4. RECENT IHI EFFORTS FOR PRODUCTIVITY IMPROVEMENT

IHI has been increasing its productivity by an average of 5 percent per year as mentioned before. This improvement tends to be offset by wages and various yard expenses which have been rising every year. Therefore, IHI has been trying to keep down all costs such as energy expenditures, any facility investment not absolutely necessary, and overhead charges. The following section describes some examples of IHI's efforts.

4.1 DESIGN AND ENGINEERING

4.1.1 Recognizing the Role of the Design Department

IHI design engineers widely accept the concept of Dr. Shinto, who advocates the role of the Design Department as follows:

"Designing is the beginning and end of production engineering" and it consists of the following four functions:

- o Determine the shape of the ship with defined functions and performance.
- o Examine with what materials, equipment, and methods a ship can be built inexpensively and quickly while satisfying the defined functions and performance specifications, express them as drawings and other documents.
- o Supply to the Material Procurement Department within a defined time schedule, information on specifications, quantities, and delivery dates for materials. Supply to the Manufacturing Department, drawings and work instructions for respective production processes within defined time schedules.
- o Analyze at both the completion and during the building processes the differences between estimates and actual figures in terms of costs, quality, and performance and plan to incorporate improvement in the next ship to be built."

(1) Responsibility Regarding Costs

Design engineers cannot contribute to cost reduction as long as they consider their job as simply producing drawings. They should be aiming at minimizing production man-hour requirements.

Also, the reduction of material costs, which consists of about 60 percent of a ship's cost, is extremely important and the design process plays a vital roll. The Design Department is responsible for reducing the total

quantity of materials, while the Procurement Department is responsible for reducing cost per unit. Of course, the Design Department also makes efforts to select the most inexpensive and easily providable materials.

Reducing total material quantities and material categories leads to the reduction of production man-hours.

In IHI the Design Department itself manages both budget and actual figures regarding material quantities.

Table 4 Material Budget/Actual Comparison

ZONE	SYSTEM	ITEM	QUANTITY ESTIMATED *1	QUANTITY EXECUTION PLAN *2	QUANTITY ACTUAL *3		QUANTITY AT TIME OF SHIPS COMPLETION *4
					(R1)	(R2)	

*1 Quantity estimated for Contract price prepared by Headquarters.

*2 Execution plan is prepared by Design Division in the Shipyard during functional design development.

*3 Actual quantities are issued when functional design is completed and again when detail design is completed.

*4 Actual quantity used for completing the ship

(2) Responsibility in Information Provision

The Designing Department is responsible for providing the Material Procurement and Manufacturing Departments with timely and necessary information.

Although the Design Department should supply to the Material Procurement Department the specifications for all the materials required and their confirmed quantities within a time frame requested by the Material Procurement Department, it is usually extremely difficult to do so. For the quantities not determined, the Design Department supplies provisional estimates and replaces them with the confirmed quantities when they are determined. While the Design Department supplies to the Material Procurement Department the information on all the material quantities, it should also provide the Manufacturing Department with material data as early as possible. The latter uses material data as the base of its master construction schedule and manning plans.

The main items of the data are:

- o Hull steel weight ... each block
- o Welding length ... each block
- o Parametric out each zone
fitting weight
- o Pipe weight, each zone
number of pieces
- o Cable length each zone

Delay in the drawing issues leads to delay in the material marshalling which further contributes to confusion in production work flows. Thus, design process management preparation is most important. Drawing issues must meet the master construction schedule, while keeping in mind that the manufacturing schedule must be suitable for material lead times.

Thus, the Design Department is not in a position parallel with other departments. Instead it is in a position for leading them. The Design Department's performance determines the performance of the whole shipyard.

4.1.2 Module Design and Learning Effect

The basic concept of the cost reduction strategy is how to utilize the learning effect. A new ship is designed by locating a ship similar to the new one. Records of that ship-building history are used as a model. IHI calls this procedure the "Module Design". That is, if parts of ships are similar, design modules from the previous history are adopted as is or with some improvement. It is important not to waste energy and resources in treating every new design as if there was no precedent.

After selecting the model ship, the Design Department examines the difference between the already known actual costs and total material quantities and the target costs for the new ship. Then, it analyzes how and where the improvements could be made to reduce costs. For identical and similar modules, design man-hours and production man-hours are reduced due to the learning effect.

The data accumulated is the company's valuable property. In order to utilize the data easily the accumulation should take the form of modules of drawings and material lists. Retrieval of and combining this type of data have proved to be effective by using the CAD system.

Of course, even with modules new concepts are involved. But, routine module design methods assist engineers to concentrate their creative energy in the new aspects.

4.1.3 Information Development and Integration in Design

In the design process, a great amount of information must be created with high precision in the relatively short period allowed for basic, functional, transition, and detail design.

Computer processing has been utilized in IHI shipyards for two decades. The processes were quite independent from one another until about 1984. Now they are fully integrated.

In the beginning of the 1970s, IHI computerized ship calculations, lines, structural analysis, etc. for functional design and computerized hull structural parts generation and pipe details for detail design. In addition material control was computerized.

Later, the system was expanded and improved in its effectiveness. But, the integration among the various systems was accomplished by batch processing using drawings as a common reference. The system was insufficient as a "data base". Operational efficiency approached an inherent limit.

Therefore, IHI decided to modernize the design process by developing and using FRESKO (Future Oriented Engineering System for Shipbuilding

aided by Computer) in order to establish a total integrated system for all data as shown in Figure 7.

FRESKO consists of FRESKO-H (Hull Structure) and FRESKO-F (Outfitting) and integrates everything from basic design, functional and transition design to detail design. With this system, information is utilized in an integrated manner while simultaneously replacing manually prepared drawings with computer processing.

The FRESKO design functions include automatic design, module design, and interactive design by freely combining all of them. It is a flexible design system capable of efficient information processing.

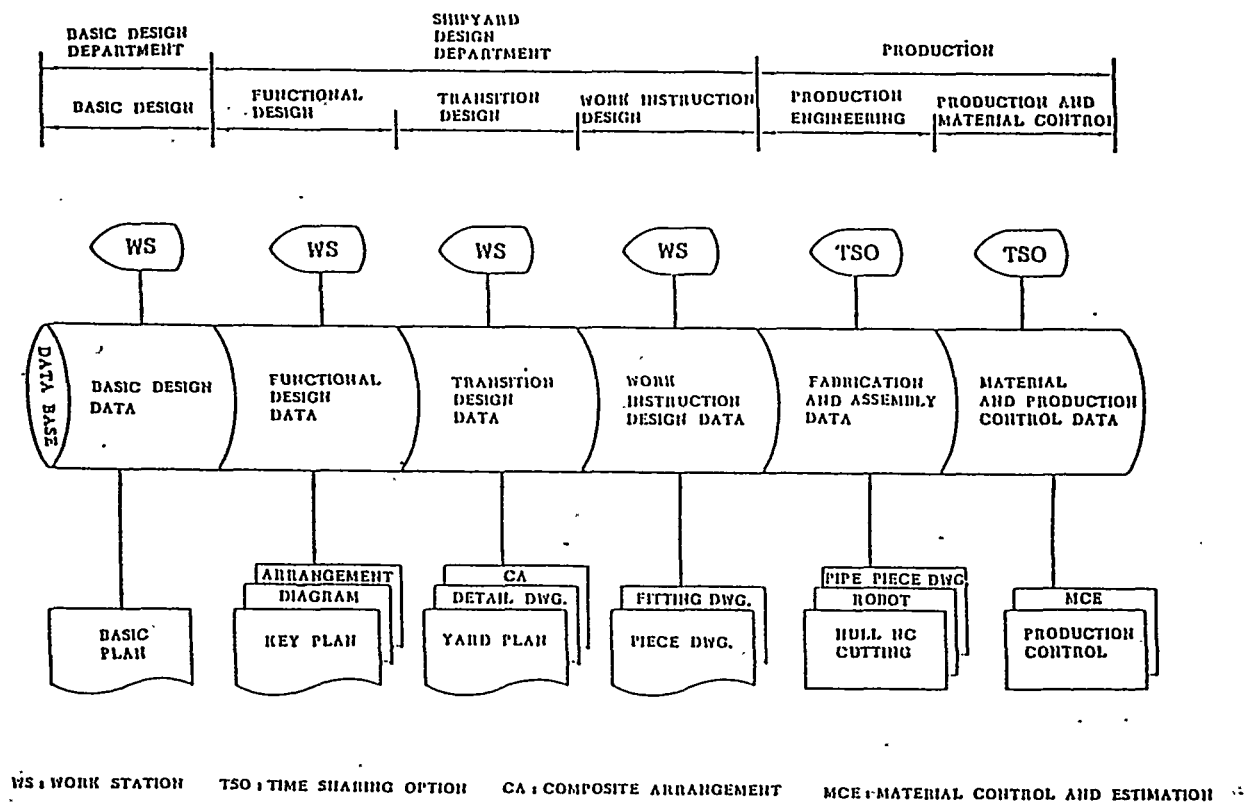


Figure 7. Coverage of Fresco system

The following section describes the characteristics of the FRESCO system.

- o Since the information is coherent, once created and entered, information can be used downstream in an integrated manner. Only the information not included in the system is retrieved from or added to the data base by dialog.
- o By standardizing the function configuration and drawings, the existing drawings can be reutilized flexibly and widely.
- o By standardizing the materials and practices, a total composite drawing can be produced quickly by computer using the data such as various functional diagrams, namely system diagrams and machinery arrangement drawings. While producing the drawings, the material procurement list can be made simultaneously.
- o By standardizing the work unit, while producing the drawings, a pallet list (material package required for the work) can be made for the most appropriate production and production control.

Figure 8 describes the coverage of the CAD system and CAD overall hardware system.

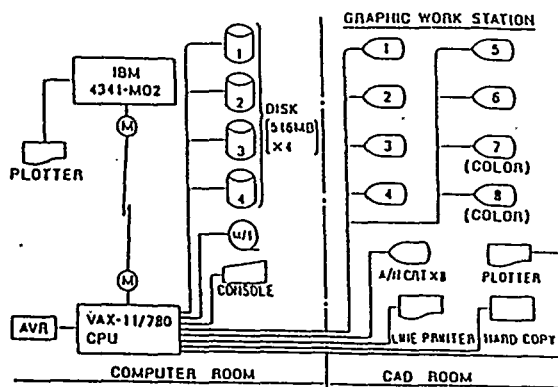


Figure 8. Fresco hardware system

4.2 PRODUCTION FACILITY AND PRODUCTION ENGINEERING

IHI completed its facility expansion and modernization by the 1970s. Since then, IHI has been executing only small scale facility improvements, mainly modifying facilities for raising productivity and for responding to increased diversification.

The productivity improvement is concentrated on:

- (1) Increasing automatic machine installations
- (2) Improving the work environment
- (3) Improving various hand tools and jigs

The following are representative improvement items in IHI Kure shipyard:

- (1) Increasing automatic machine installations

o Welding related items

Submerged arc welding and the gravity welder were the two main welding methods supporting productivity. IHI gradually introduced a great number of the advanced CO₂ semiautomatic welding machines which now dominate.

The automation rate* in welding has improved by 20 percent in the past 5 years, reaching 70 percent by now. Since more than 20 percent in the remaining 30 percent is by the gravity welder, traditional stick welding is no longer in normal use.

* Welding automation rate:

Automatic and semi-automatic welding wire weight / Total welding wire weight x 100%

o Burning machines

In addition to the E.P.M. (Electro-Photo-Marking) N/C Gas Burning Machines, IHI has introduced Plasma Burning Machines. The machines are used for different situations with flexibility according to their characteristics.

o Automatic Machines, Robots

IHI has produced a welding robot on a trial basis. However, it has not yet reached the evaluation stage.

(2) Improvement of work environment

o Working Area Enclosing Mobile Structure

IHI has made all the zone outfitting areas weather proof (all weather type) by establishing mobile structures over them.

o Simplified Scaffolding Units

IHI abolished conventional scaffoldings and adopted simplified scaffolding units which are combinations of steel landings, rails, and ladders. Each is a sort of staging package moved by crane. By adopting this system, stage building man-hours were greatly reduced.

o Installation of remote control devices on shop cranes.

This installation has reduced the number of crane operators and improved work safety.

(3) Improving hand tools and jigs

IHI switched from the heavy air driving portable grinder and chipping hammer to lighter electric type machines with better performance. This shift not only improved efficiency but also contributed to electricity conservation. Replacing the chipping hammer with electric grinders, reduced noise and contributed to work environment improvement. Innumerable improvements, most of which were suggested by the workers themselves, were made regarding other hand tools, jigs etc.

4.3 REFINED EFFORTS FOR PRODUCTIVITY

The production system, production engineering, and production facilities are not purposes but means.

Their purpose is to improve productivity and quality. Simultaneously, IHI uses objective criteria with concrete measuring units in order to monitor progress. Otherwise, it is not possible to understand and find solutions to problems.

IHI's Productivity indicators are;

o Hull structural steel:

man-hours/ton of hull weight
welding length/man-hour

o Hull outfitting:

man-hours/ton of parametric
outfitting weight

o Pipe fitting:

man-hours/ton of pipe weight
man-hours/pipe piece

o Electric fitting:

man-hours/cable length

o Painting:

man-hours/area

o Ship total:

Total man-hours/CGT*

* Compensated gross tonnage

The following data are included in the statistics as items indicating quality which impacts on productivity.

o Welding quality:

X-ray defect rate;
Defects/Inspected number

o Shell precision:

Gas cutting rate;
Gas cutting length/Erection gap
length

Back-strip welding rate;
Back-strip welding length/
Erection gap length

o Pipe precision:

Pipe remanufacturing rate;
Remanufactured number/Total
number

o Steel yield:

Net weight/Invoice weight

o Palletizing completion degree:

Loss rate;
Lost line items/Total line items

By using the indices, it is possible to examine productivity quantitatively, and to establish targets for productivity increases.

4.4 ORGANIZATIONAL ACTIVATION

4.4.1 Importance of Target Management

Motivating workers is one of the important elements for improving productivity in shipyards. The final factor in production is the workers themselves. High quality production systems and facilities cannot guarantee a good production pace without their cooperation. Without strong motivation of the workers, productivity cannot improve. Usually in production sites, a situation interfering with smooth production occurs almost everyday. For example, equipment failure, material shortage, absence of workers, and product defects, can occur anytime. The workers find those problems first. Unless they take necessary action with a positive attitude or report to their supervisors for solving the problems, the impact on production cannot be minimized. The production system alone cannot cover such problems. The key here is the motivation of workers toward production. It is important to continue motivating the workers so that their positive attitude becomes a custom.

What kind of work purpose do the workers have?

In IHI the workers have their own targets such as "welding an average of 6 m per hour", "mounting 8 pipes per day", "completing a block by the end of the week etc." They all cooperate so that their targets can be attained without a great amount of difficulty.

4.4.2 Target Management and Small Groups

IHI has more than 15 years of history in small group activities. Each small group usually consists of about 10 members employed at the same work site. An assistant foreman usually assumes the role of the selected leader. Thus, each small group is the smallest size unit for yard management. The small group has a quantitative management target and its members cooperate with one another in order to achieve the goal.

The head of the target management hierarchy is the Shipyard Manager. Once a year a yard level target is set defining responsibility of the groups. The targets are set at the respective levels such as the level of the Shipyard Manager, Department Manager, Section Manager, Foreman, and Small Group.

Target achievement by each small group supports the target set by the section the group belongs to. In the same manner, the target achievement of the section supports the department and so on. Therefore, the shipyard as a whole is a cooperating body to improve productivity and product quality. A client who places an order with a shipyard with this kind of spirit and production system has great assurance for timely and quality performance. Recently, some owners have abandoned dispatching owner representatives for supervising the work. Such clients fully trust IHI.

5. ADVICE TO U.S. SHIPYARDS

IHI shipbuilding technology has been adopted in many shipyards in the United States in various areas and has proved its effectiveness. The following points are suggested, based on experiences of IHI managers who served as consultants in U.S. yards:

5.1 DESIGN

- (1) The Design Department, as mentioned in 4.1.1, should have a strong role. It should not consider its own role as a department parallel to Material Procurement and Production Departments. It should clearly recognize its leading role for generating accurate and timely information.
- (2) The Design Department should execute scheduling management of its own work as in the Production Department. The former's scheduling management system should precisely correspond to those of the Material Procurement and Production Departments.
- (3) Adopting a totalized CAD system
The information should be rectified according to priority and systematized. Excessive information should be avoided. Module design, utilizing CAD, should be employed.
- (4) Preferably contract design and subsequent design phases should be performed in-house. This permits a shipyard to impose a building strategy.

5.2 PRODUCTION FACILITY

- (1) It is too early to adopt large size high-tech robots. Replacing and modernizing manual welding and cutting machines with automatic machines should be given priority.

Compared to Japanese shipyards, the adoption of gravity welders in the U.S. is far behind.

- (2) Sub-assembly line, panel line, belt conveyor

The United States is behind in adopting conveyers for fabrication, sub-assembly and assembly lines. The major production line must maintain a defined speed. If this line is manual, the production speed may become unstable. The best solution is to adopt a conveyor line which sets the pace of production.

- (3) Abolishing outdoor work

In U.S. shipyards, more work is executed outside. The work environment can be improved by adopting covered work sites.

- (4) Facility improvement to reduce man-hours

Improve the crane system by adopting remote controls and improve jigs and tools for use by one worker.

5.3 PRODUCTION ENGINEERING

- (1) Index expressing productivity, precision, and quality

Utilize the indices described in 4.3 as the criteria for level loading. Use them for future improvements.

- (2) Process lane system

Some U.S. shipyards significantly improved productivity by adopting process lanes.

Smoothly shifting from the conventional craft system to one with different crafts working together in the same process lane is a key to success.

- (3) An independent "Production Planning Department" is ineffective for accurately budgeting man-hours and scheduling. Such activities should be implemented primarily by the Production Department and should be decentralized. The same people should have both budgeting and scheduling functions. Dividing the two is not wise since it leads to unclear definition of responsibilities.

5.4 ORGANIZATIONAL ACTIVATION

- (1) Practice of Target Management

Target setting should be executed in a hierarchical manner from top management to the first-line supervisor. Then concrete targets should be set, implemented, and their results should be evaluated.

- (2) Introduction of Small Group Activities

Without a firm base, the introduction of this system is rather difficult. However, if target management is implemented, a small group can achieve a reasonable target set by its first-line supervisor.

- (3) Communication Promotion

The Design Department should promote communications with itself and with the Production and Material Procurement Departments.

5.5 COOPERATION WITH NAVY

Although the comments and advice in the foregoing sections are based on IHI experiences for commercial ships, most of the advice also applies to Naval ships. In fact, most of the methods have been applied for building Naval ships in an IHI shipyard.

Commercial ships and Naval ships share the same basic functions. It is true that in the case of Naval ships the emphasis is on functions with more complex systems and the cost factor is not as important as for commercial ships. There is not much latitude for improvement by a shipyard when a Navy imposes traditional ways regarding drawing types and contents, composition of progress reports, and progress payments. Some consider this situation as the factor that prevents improving productivity. Considering the fact that at present ships built in the United States are mainly Naval ships, U.S. shipbuilders should actively solicit the Navy's cooperation for productivity improvements.

6. CONCLUSION

- (1) Some shipyards in the United States have been modernized and their production systems appear to have reached an upper limit of improvement. But, there is still a vast gap in productivity between Japanese and U.S. shipyards. Productivity can be further improved in U.S. shipyards by improving management of the human element.

Management's task is to create in the present systems an environment where workers can implement their roles thoroughly unencumbered by problems that workers can do nothing about.

It is easy to understand why the productivity ratio between Japan and the United States in shipbuilding is 2:1. In the United States, "there are too many workers", or, "human input is more than necessary".

This difference originates from differences in management attitudes. In the United States, when work is delayed, management increases man power. Japanese management examines why work is delayed. After analysis of the total work load and number of workers, usually decisions are made to increase the use of machines and jigs to assist workers without increasing their number.

- (2) In old days, the low cost of Japanese ships was caused by cheap labor. But, today Japan is one of the countries with a high wage level. Can the shipbuilding industry survive in a country like Japan with a high wage level?

We have to make it survive.

Japanese shipbuilding facilities were reduced by 35 percent in 1978 and another large scale reduction is underway.

IHI, however, will not withdraw from the world market. The present move is a facility adjustment corresponding to world demands and expected market share by IHI. In other words, the facility reduction is for survival.

The following is a bright topic for IHI and for the Japanese shipbuilding industry as a whole:

IHI won in an international bid for a 230,000 DWT VLCC over Korea, Taiwan, and European countries. The owner's decision was made based on not only the price but also on IHI superior technology, especially regarding fuel consumption rate.

- (3) Cultural and social custom difference is often cited in explaining the gap in the productivity between shipbuilding industries in Japan and the United States. This is an incorrect assumption. It is difficult to find a base for believing that

productivity improvement in the United States is so limited.

- (4) Today, the United States remains an admirable and strong economic power. Its manufacturing industries should obtain more international competitiveness by establishing a more balanced industrial structure. Shipbuilding is no exception.

I should be honored if this paper can contribute to productivity improvement in the U.S. shipbuilding industry.

Finally I should like to express my deepest gratitude for Mr. H. Nishi, Mr. Y. Okayama (IHI) and the people who cooperated in writing this paper:

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